SOUTHEAST PARTNERS IN AMPHIBIAN AND REPTILE CONSERVATION

Conservation Action Plan

Green Salamander (*Aneides aeneus*) Species Complex

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Introduction

According to the IUCN Red List of Threatened Species, the green salamander (*Aneides aeneus*) is listed as "Near Threatened" (Hammerson 2004). In 2012, the U.S. Fish and Wildlife Service (USFWS) was petitioned to protect 53 species of reptiles and amphibians—including the green salamander—under the Endangered Species Act. Although the petitioning organization rescinded the petition in order to review upcoming taxonomic changes, the process identified many knowledge gaps for the species, including relative population abundance, distribution, dispersal patterns, life history traits, behavioral attributes, and the implications of the direct and indirect threats for conservation (USFWS 2015). Addressing these knowledge gaps will help us to continue to adapt management guidelines for green salamanders and ensure best practices for conservation.

Green salamander populations, particularly in the Blue Ridge Escarpment (BRE; which covers North Carolina, South Carolina, and Georgia), have declined over the past several decades possibly due to habitat loss, disease, overharvesting, and climate change (Corser et al. 2001; Hammerson 2004). The conservation management practices described in this report are recommendations to combat the threats to green salamanders. Partners, including governmental agencies, natural resource managers, non-profit organizations, zoos and aquariums, and academic institutions, will likely play important roles in the conservation of these species.

Species Profile

Taxonomy: Green salamanders belong to the lungless family of salamanders (Plethodontidae) and respire completely through their skin. Like other species in the genus *Aneides*, green salamanders are excellent climbers. The name, *Aneides,* is Greek for "lacking form or shape", in reference to their flattened, elongated bodies. The species epithet, *aeneus,* is Latin, meaning bronze or copper, and refers to their dorsal coloration (Mount 1975; Petranka 1998). A recent genetic study proposed that the species actually represents four distinct lineages, including one lineage that was described as a separate species, the Hickory Nut Gorge green salamander (*Aneides caryaensis*, Patton et al. 2019). The remaining three lineages are currently recognized together as *A. aeneus* but may eventually warrant recognition as distinct species (Patton et al. 2019). Because conservation requirements are likely similar between species, and literature prior to 2019 does not differentiate between *A. caryaensis* and *A. aeneus*, this report refers to both species collectively unless specified otherwise.

Figure 2. Green salamander coloration can provide camouflage among moss and lichen. Photo: Jill Newman

Description: Adult green salamanders range from 7.6 to 14 cm (3–5.5 inches) in length, with females generally longer than males. Their coloration varies from mottled greenish, yellow, brown, or black with lighter underbellies (Figures 1–2). This coloration aids camouflage among lichen and moss-covered tree bark and rock outcrops. They are dorsoventrally flattened, with long limbs, and a rounded tail. This body shape allows them to hide in the narrow crevices of rocks and trees. Their squared toe pads (Figure 3) assist with climbing vertical surfaces such as trees and cliffs (USFWS 2019). In addition to their slightly shorter length, males can be distinguished from females by their elongated teeth and mental gland which they use for courtship (Petranka 1998; John 2016). The appearance of *A. aeneus* and *A. caryaensis* is similar, but the two have subtle morphological differences—*A. caryaensis* has a broader head and shoulders, longer toes, and a greater number of teeth (Patton et al. 2019). Additionally, the coloration pattern of *A. caryaensis* is characterized by smaller and less connected green patches and a darker base color (Figure 1).

Figure 3. Green salamander toe pads Photo: Gary Nafis

Habitat: Like other plethodontid salamanders, green salamanders require cool, moist environments to enable gas exchange through their skin. Suitable habitat for the species is limited to locations that have both a mature forest canopy and rocky outcrops, caves, or cliffs (Figure 4). Crevice size and humidity are also important factors (USFWS 2019). These species also use arboreal habitats including trees, rhododendron, decaying tree bark, and downed logs (Waldron and Humphries 2005). Arboreal habitats were once considered secondary to rocky habitats; however, studies now suggest that habitat preferences shift seasonally, with trees serving as the primary habitat from May to September (Waldron and Humphries 2005). Green salamanders hibernate in deep rock crevices during the winter. During the breeding season, females require brooding crevices (e.g., rock crevices, decaying logs) to suspend their eggs (Figure 5). Adults and juveniles are distributed throughout similar habitats; however, juveniles are more likely to occupy trees than adults (Waldron and Humphries 2005). Research suggest that green salamanders are more abundant in habitat at lower elevations with south-facing slopes (Bruce 1968; Newman et al. 2018a; Williams et al. 2020).

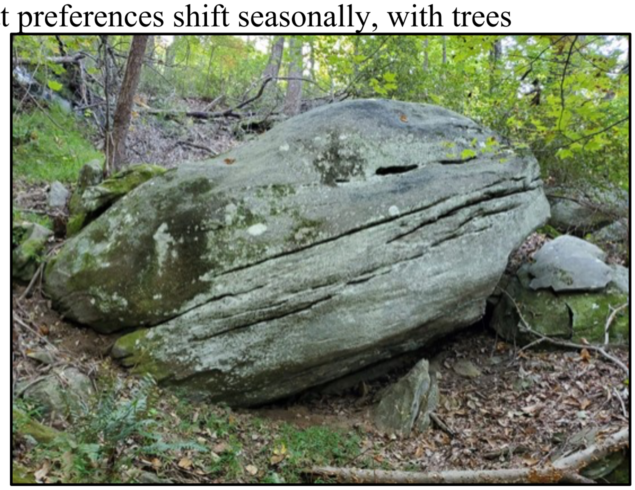

Figure 4. Rocky outcrop with crevices used by green salamanders. Photo: Jill Newman.

Life History/Behavior: Although many salamanders are primarily nocturnal, green salamanders may be active either at night (Cupp 1991) or during the day (Newman et al. 2018a). Interestingly, preliminary laboratory studies suggest that green salamanders may be more resistant to desiccation than other plethodontids (Gordon 1952; Canterbury 1991). During winter (December–March), they remain largely inactive.

The breeding season begins in May and can last until late September. Males reproduce every breeding season, whereas females breed every other year, laying a single clutch of 10 to 30 eggs (Smithsonian's National Zoo & Conservation 2018). Eggs are suspended on the ceiling of a rock crevice with mucus (Figure 5). Females forego foraging and remain within the brooding crevice after laying eggs (John 2016). They guard their eggs aggressively until the offspring hatch, usually 2.5 months later. Because of the maternal attendance, nest success is usually high and ranges between 73–92% (Rossell et al. 2019). The offspring have direct development and lack a larval stage. Hatchlings resemble smaller versions of adults. Juveniles stay with their mother for two months after hatching. Dispersal movements by hatchlings from the rock outcrops have also been observed (Gordon 1952; Newman et al. 2018b).

Green salamanders may reach sexual maturity as young as three years of age. However, some reports indicate that it can take eight years for individuals to mature (Waldron and Pauley 2007). Although the average lifespan for green salamanders is unknown, individuals have been reported to survive 20 years in captivity and over 13 years in the wild (Waldron and Pauley 2007). Predators of green salamanders generally include snakes and lizards that can fit inside the rock crevices they occupy. The usual prey base for the species is comprised of a variety of invertebrates, including arachnids, insects, slugs, and snails (Smithsonian's National Zoo & Conservation 2018).

Figure 5. Brooding crevice w/green salamander. Photo: Tom Mann

Range: The range of the green salamander extends across the Appalachian region, with isolated populations along the Allegheny Plateau and the BRE. The current range for the species extends discontinuously from northeastern Mississippi and northern Alabama to southwestern Pennsylvania. Isolated populations have been recorded in southern Indiana and central Tennessee (Hammerson 2004). The species is found at elevations between 140–1350 m with the highest occurrences recorded in North Carolina and Kentucky (NatureServe 2021). The Hickory Nut Gorge green salamander is found only in North Carolina (Buncombe, Henderson, Polk, and Rutherford counties).

Population Trends: With few long-term studies, trends for green salamanders in many regions are unknown. Populations in the BRE have been the subject of long-term study. Before the 1970s, high densities of the green salamander were reported in the BRE (Snyder 1983; Corser 2001). Subsequently, the BRE population in South Carolina likely dramatically declined during the early 1970s (Mitchell et al. 1999). In the 1990s, further study of 7 sites in the BRE observed a 98% decline in relative abundance compared to reports of the same sites in the 1970s (Corser 2001).

Although 6 additional sites were discovered and monitored in the 1990s, 3 of the 6 declined substantially between 1996 and 1997. Results determined that the declines had no correlation with initial population size, elevation, or forest community type. Instead, the decline was attributed to habitat loss, epidemic disease, collection, and/or climate conditions (Corser 2001).

Efforts to resurvey BRE populations in North Carolina (Williams et al. 2020) and South Carolina (Newman et al. 2018a) have provided more recent information on green salamander abundance and occupancy in this region. In South Carolina, green salamanders were detected in 23 of the 51 sites historically occupied. In North Carolina, 44 of 57 historical sites were occupied by at least one individual (Williams et al. 2020). However, even extant populations in North Carolina appear to have been greatly reduced in abundance.

Comparable long-term data for the species in other parts of the range is limited. For the Tishomingo population in Mississippi, four sites that were previously surveyed in 1967-1968 and 1987-1990 were later resurveyed in 2008-2009. Despite reports that one site had been extirpated between the surveys in the 1960s and 1990s, all four sites were occupied in the 2008-2009 survey (Rauch et al. 2016).

Although surveys can provide some insight into population trends, individual survey results should be interpreted cautiously. Green salamanders often occur at low numbers and are difficult to detect even when present (Newman et al. 2018a). Because detection can also be affected by many factors including time of survey (Newman et al. 2018a), weather conditions (Smith et al. 2017), and season (Williams et al. 2020), repeated surveys are needed to determine occupancy and abundance and assess trends in a population. Therefore, it is important not to assume the species is absent from a site based on limited survey efforts. For comparisons between populations and sampling occasions, it is also important to employ the same methodologies between surveys.

Threats: Threats to the green salamanders include large-scale habitat loss and degradation, disease, poaching, and climate change (Mitchell et al. 1999).

1. **Habitat Degradation**: Because green salamanders prefer old-growth forests (Waldron and Humphries 2005), logging reduces suitable habitat for the species (Wilson 2001). Although green salamanders spend a significant amount of time in rock outcrops (Corser 2001), tree removal can reduce canopy cover needed to shade rocky outcrops as well as habitat needed for foraging.

2. **Habitat fragmentation:** Green salamander subpopulations are fragmented and isolated. Although green salamanders move between neighboring rock outcroppings, they are limited

in their dispersal capacity (John et al. 2019). Roads create greater isolation and increase airflow, thereby decreasing the moisture in remaining forests. Restricting movements will further limit gene flow between populations. Research conducted on genetic distances between subpopulations of the green salamander concluded that gene flow can occur within a one-kilometer radius but is diminished at three-kilometers (Johnson 2002). Isolation and fragmentation of these small subpopulations could result in reduced genetic diversity and potential inbreeding within the species.

3. **Mining**: Another major threat to green salamanders is surface mining. One type of surface mining is mountain top removal mining which eliminates forests and rock layers from mountain tops to gain access to coal. Another type of surface mining is strip mining which eliminates rock layers adjacent to a rock outcrop to gain access to coal and other minerals. According to the Office of Surface Mining Reclamation and Enforcement, West Virginia had 300,000 acres of active mountain top removal mining permits which amounted to approximately 2% of the entire state's total land area (OSMRE 2007). These practices are especially devastating for green salamanders as entire ecosystems are altered. Even when mining sites are reclaimed, green salamander populations are slow to recover and may be found in decreased abundance relative to mature forests years after the reclamation occurs (Wood et al. 2013). In some cases, green salamanders may be able to survive at remnant rock outcrops surrounding mines (Hinkle et al. 2018), but additional research is required to assess the health and viability of salamander populations occupying these fragmented landscapes.

4. **Disease**: Emerging infectious diseases are an increasing threat to amphibians. Chytridiomycosis, the disease caused by *Batrachochytrium dendrobatidis* (*Bd*) and *B. salamandrivorans* (*Bsal*), has contributed to drastic declines in many amphibians globally (Lips et al. 2006; Lötters et al. 2009; Fisher and Garner 2020). Ranaviruses are also common perpetrators of amphibian die-offs in North America (Miller et al. 2011). Ranavirus infections have been reported in 11 species of plethodontid salamanders in the Great Smoky Mountains (Sutton et al. 2015). In 2015, the first in-depth study on green salamander pathogen prevalence was conducted in southwestern Virginia and documented an 8% prevalence for ranavirus and 15% prevalence for *Bd* (Blackburn et al. 2015). Two other studies, one in North Carolina and one in South Carolina, demonstrated similar results, showing low prevalence of disease in their respective states (Moffitt et al. 2015; Newman et al. 2019; Lentz et al. 2021). Because some species are resilient to certain pathogens, infection does not always lead to disease. However, recent research found that some other lungless salamanders are susceptible to disease when infected with *Bsal* (Carter et al. 2020; DiRenzo et al. 2021). These results suggest that green salamanders may also be at risk, should *Bsal* become established in North America.

5. **Climate Change**: Increasing temperatures predicted by climate models could negatively impact salamanders by reducing moisture and increasing desiccation rates. Because salamanders are ectotherms, metabolic rates may also be affected (Riddell and Sears 2020). In the Appalachian Highlands, models predict a reduction in habitat due to climate change

for multiple salamander species (Milanovich 2010). A correlative distribution model for green salamanders illustrated a 93% loss in suitable habitat by 2050 (Barrett et al. 2014). Additional risks associated with climate change include droughts, severe storms, and fluctuating weather conditions. Adverse weather conditions have been suggested as a factor in population declines (Corser 2001). Phenology, the timing of life cycle events, can be affected by the resulting shifts of seasonal temperatures due to climate change. Breeding and overwintering timelines could be disrupted for many amphibian species, including the green salamander. The temporal shift in breeding activity may also leave amphibians exposed to harsher weather conditions (Olson and Saenz 2013).

6. **Over-collection.** Green salamanders are sometimes poached for pets or collected by researchers. The species may be particularly sensitive to collection because females only breed bi-annually and take several years to reach sexual maturity (Petranka 1998).

Conservation Status

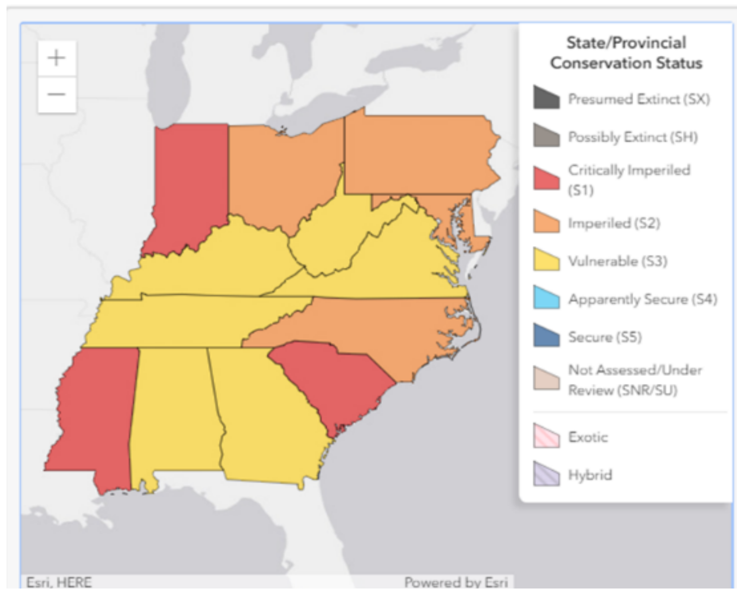

Figure 6: The State Conservation Status for the green salamander across its distribution (NatureServe 2011).

The IUCN Red List of Threatened Species classifies the green salamander (*Aneides aeneus*) as "Near Threatened". The green salamander is currently listed as "Endangered", "Threatened", "Protected", "Rare", or "Of Special Concern" in 10 out of the 13 states where the species occurs, with only Virginia, Tennessee and Kentucky lacking a designated listing. In North Carolina (the only state with both green salamander species), *A. caryaensis* was recently classified as "Endangered" while *A. aeneus* was listed as "Threatened". Green salamanders are listed as "Endangered" in Indiana, Maryland, Mississippi, and Ohio. In Pennsylvania they are "Threatened". Green salamanders are "Protected" in Alabama and Georgia and a "Species of Concern" in South Carolina, and West Virginia. Although they are not listed in Tennessee, Virginia, and Kentucky, these states have included the species in their State Wildlife Action Plans, as have all other states.

In addition to official state listings, NatureServe—a non-profit organization that collaborates with numerous state and private conservation entities—also lists the species as "Vulnerable" (G3) and provides a standardized listing for each state (Figure 6). Because the Hickory Nut Gorge green salamander (*A. caryaensis*) is found only in North Carolina, it is considered "Critically Imperiled" (G1) by NatureServe.

Recommended Conservation Implementation Strategies

The specific habitat requirements of green salamanders make it imperative to protect rock outcrops and surrounding forests. Listed below are best management practices, which are based upon existing knowledge of the natural history of and threats to these species:

1. **Create a buffer around rock outcrops**. Because rocky habitat is essential for overwintering, protecting this habitat is critical to the conservation of these species. It has been suggested that a 100m buffer will help maintain tree cover around rocky areas will help keep rocks shaded and moist (Petranka 1998; Wilson 2001; Waldron and Humphries 2005; Newman et al. 2018a).

2. **Plant trees in deforested areas.** It may be beneficial to plant hardwood trees near rock outcrops, as they are the preferred arboreal habitat of green salamanders (Waldron and Humphries 2005). The shade provided by trees also prevents direct sun exposure and helps maintain the humid environment required by these species. (Virginia Herpetological Society, n.d.). Leaf litter provides cover for salamanders as they move between rock outcrops and trees (John et al. 2019). Dead trees may also provide habitat for invertebrate prey, as has been suggested in another study that assessed the diet of the congeneric clouded salamander (Whitaker et al. 1986).

3. **Prohibit collection of green salamanders and manage sensitive data.** Sudden crashes in green salamander populations may relate to the overcollection of individuals (Corser 2001). Small populations are susceptible to environmental and demographic stochasticity, and any decreases in population size further increase these risks. If protected at the state or local level, this status and any penalties for unauthorized collection or handling should be clearly listed on relevant webpages or any other educational materials about the species.

   Although community science initiatives can be helpful tools for identifying green salamander populations (Smith et al. 2015), the potential benefits of such initiatives must be balanced with the risk of illegal collection. Avoid releasing the exact locations of known populations in presentations, publications, or educational materials. Data sharing agreements between individual states when working with sensitive species, such as the green salamander, could hold users responsible to established standards and provide secure ways to leverage data without sharing sensitive information online.

4. **Monitor populations.** Long-term monitoring is important for assessing the population dynamics of the species and may provide earlier warnings if a decline occurs. Long-term monitoring may also provide needed information about the ecology of these species, particularly as it relates to changing environmental conditions. Additional surveys in areas that have suitable habitats for green salamanders may reveal new populations.

5. **Conduct demographic field studies to assist with identifying vulnerable life-stages.** Field experiments could provide more details regarding green salamander natural history, including water-loss tolerance, preferred micro-habitat, and survivorship at different life-stages. Demographic information for a species is important when making conservation decisions because it can help identify life-history stages (egg, juvenile, adult) most vulnerable, as well as identify the stage(s) where management will be most effective.

6. **Practice good sanitation practices when conducting field work.** Pathogens can inadvertently spread through research and monitoring activities. To minimize the potential spread of pathogens, disinfect all equipment with 3% bleach (or other suitable disinfectants) between study sites, and if handling salamanders, change gloves before processing each individual (see NEPARC Disinfection Guide for more detail, link in additional information section). If you encounter green salamanders or other amphibians that appear diseased or unhealthy, report findings to the PARC Disease Task Team (herpdiseasealert@parcplace.org).

Partnering

1. **Partners in Amphibian and Reptile Conservation (PARC).** This organization focuses on the conservation of amphibians and reptiles at a national level. PARC manages 5 regional offices that aid in assessing the regional challenges of herpetofauna. The green salamander complex range extends into states belonging to 3 different regional chapters (SEPARC, NEPARC, and Midwestern PARC). As such, the organization could assist in coordinating green salamander conservation efforts between regions.
2. **Species Experts.** Species experts are also highly valuable for contributing insight into the natural history of green salamanders and serve as excellent resources to land managers and others charged with conservation of these species. The list below is not comprehensive. If you have questions about how to conserve green salamanders on a property you manage or wish to be connected with an expert, please contact PARC by visiting: https://parcplace.org/network/parc-partners/.
    a. Lori Williams, North Carolina Wildlife Resources Commission
    b. Walter Smith, University of Virginia at Wise
    c. Matt Elliott, Georgia Department of Natural Resources
    d. Matthew L. Niemiller, University of Alabama in Huntsville
    e. J.J. Apodaca, Amphibian and Reptile Conservancy
    f. Jillian C. Newman, Florida Fish and Wildlife Conservation Commission

Inventory and Monitoring

Extensive inventory and monitoring of the existing subpopulations of this species could address the gaps in knowledge for the species' life history and provide insight into the status of populations. The appropriate methods depend on 1) the question being asked 2) the intended approach for analyzing data and 3) the resources available.

In cases where green salamanders have not yet been documented, general surveys to locate rocky outcroppings are useful. New tools, such as light detection and ranging (LiDAR), may be useful for identifying rock outcrops (Hartzell et al 2014). Although more research is needed to determine the efficacy of the approach, this technology could help locate habitat that otherwise would not be visible in other media (e.g. Google Earth imagery). Surveys to identify populations should be conducted during the species' active season (May through October). Because detection probability for the species is very low (John 2017, Newman et al. 2018a), repeated surveys are essential to determine if a potential site is occupied or not. Moreover, many factors can influence detection, including the experience-level of the observer (John 2017) and time of day the survey is conducted (Newman et al. 2018a). Recording exact locations of possible habitat will ensure the same feature can be searched multiple times.

For cases when the species has been previously documented at a site, more targeted approaches can yield the most information. Listed are some inventory and monitoring techniques suggested by PARC to provide stakeholders and land managers with the means to obtain information on abundance, diversity, and distribution of amphibians, including green salamanders (Graeter, Buhlmann, Wilkinson, and Gibbons, 2013).

1. **Area-Constrained Sampling**. Area constrained visual encounter surveys are a frequently used method of searching for salamander populations. This method entails searching historically occupied green salamander sites using a headlamp to look into crevices and shine nearby trees. These types of searches are useful in determining population abundance and distribution. Again, it is important to standardize these search methods to avoid biases and maximize the probability of successfully sampling the area. The area will need to be methodically searched to increase chances of accurately estimating the number of individuals per area.
2. **Egg Mass and Nest Counts.** Egg mass and nest counts are essential methods for providing information regarding reproduction, reproductive behaviors, and population viability parameters. Salamander species that exhibit brooding behaviors, such as females guarding their eggs (e.g., green salamanders) can often lead to an underestimation of egg masses (Rossell et al. 2019). Multiple surveys throughout the reproductive period should be conducted to obtain an accurate assessment (Graeter, Buhlmann, Wilkinson, and Gibbons, 2013). A recent study on nest success and brood crevices of green salamanders on the BRE provided essential information concerning reproductive data of this cryptic species (Rossell et al. 2019). Additional studies such as this one will further increase the current understanding of the reproductive success, behavior, and conditions for these species.
3. **Arboreal Surveys.** Following methods outlined by Miloski (2010) and Newman et al. (2018a), researchers could establish line transects around rocky outcrops to search for arboreal green salamanders. Researchers could use a headlamp for shining salamanders on trees and binoculars to see if animals are up high in the canopy. Placing burlap around trees may slightly improve arboreal observation and could improve standardization of surveys (Thigpen et al. 2010).

For each monitoring method listed; detection variables (i.e., temperature, humidity, time of day) and habitat variables (i.e., elevation, rock outcrop size, crevice size, aspect) should be recorded. Additionally, if the salamander can be safely extracted, morphometrics (i.e., total length, snout-vent length, sex, age class) and body condition should be noted. Further, although pathogen prevalence has been low in green salamanders (Blackburn et al. 2015; Moffitt et al. 2015;

Newman et al. 2019), it is important to continue to monitor for *Bd*, *Bsal*, and ranavirus. Employ sanitation practices (as described in earlier section) for all monitoring activities.

High Priority Research Questions or Important Data Gaps

Explore relationships between population dynamics and environmental characteristics

- Identify important microscale habitat variables for occupancy and abundance
- Understand how forest composition affects occupancy and abundance
- Conduct occupancy/abundance surveys for the Hickory Nut Gorge green salamander
- Describe possible impacts on climate change for green salamanders
- Determine the effects of prescribed fire on green salamanders
- Determine the effects of timber harvest on green salamanders
- Determine effective buffer sizes from land and timber management activities

Movement and spatial ecology

- Describe the movement of hatchling/juvenile green salamanders
- Identify green salamander dispersal distance from rock outcrops
- Document the seasonal migration patterns of green salamanders

Improve understandings of genetics and physiology

- Continue work of Patton et al. 2019 to describe species boundaries
- Understand the effect of water loss on green salamanders

Additional Sources of Information on Green Salamanders

AmphibiaWeb: https://amphibiaweb.org/
Amphibians and Reptiles of NC: https://herpsofnc.org/
IUCN: https://www.iucn.org/resources/conservation-tools/iucn-red-list-threatened-species
Kentucky Wildlife Action Plan: https://fw.ky.gov/WAP/Pages/Wildlife-Action-Plan-Full.aspx
NatureServe Explorer: https://explorer.natureserve.org/
NEPARC Disinfection Protocols: http://northeastparc.org/disinfection-protocol/
National Zoo: https://nationalzoo.si.edu/animals/green-salamander
Savannah River Ecology Lab: http://srelherp.uga.edu
U.S. Fish & Wildlife Service: https://www.fws.gov/southeast/tags/green-salamander/
Virginia Herpetological Society: https://virginiaherpetologicalsociety.com

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Literature Cited

Barrett, K., Nibbelink, N. P., & Maerz, J. C. (2014). Identifying priority species and conservation opportunities under future climate scenarios: Amphibians in a biodiversity hotspot. *Journal of Fish and Wildlife Management* 5:282–297.

Blackburn, M., Wayland, J., Smith, W. H., McKenna, J. H., Harry, M., Hamed, M. K., …Miller, D. L. (2015). First report of Ranavirus and *Batrachochytrium dendrobatidis* in green salamanders (*Aneides aeneus*) from Virginia, USA. *Herpetological Review*, *46*(3), 357–361.

Bruce, R. C. (1968). The role of the Blue Ridge Embayment in the zoogeography of the green salamander, *Aneides aeneus*. *Herpetologica*, *24*(3), 185-194.

Canterbury, R. A. (1991). Ecology of the green salamander: *Aneides aeneus* (Cope and Packard), in West Virginia. MS Thesis. Marshall University. Huntington, West Virginia.

Carter, E. D., Miller, D. L., Peterson, A. C., Sutton, W. B., Cusaac, J. P. W., Spatz, J. A., … & Gray, M. J. (2020). Conservation risk of *Batrachochytrium salamandrivorans* to endemic lungless salamanders. *Conservation Letters*, *13*(1), e12675.

Corser, J. D. (2001). Decline of disjunct green salamander (*Aneides aeneus*) populations in the southern Appalachians. *Biological Conservation*, *97*(1), 119–126.

Cupp, P. V. (1991). Aspects of the life history and ecology of the green salamander, *Aneides aeneus*, in Kentucky. *Journal of the Tennessee Academy of Science*, *66*, 171-174.

DiRenzo, G. V., Longo, A. V., Muletz-Wolz, C. R., Pessier, A. P., Goodheart, J. A. & Lips, K. R. (2021). Plethodontid salamanders show variable disease dynamics in response to *Batrachochytrium salamandrivorans chytridiomycosis*. Biological Invasions, pp.1-19.

Fisher, M. C., & Garner, T. W. (2020). Chytrid fungi and global amphibian declines. *Nature Reviews Microbiology*, *18*(6), 332-343.

Gordon, R. E. (1952). A contribution to the life history and ecology of the plethodontid salamander *Aneides aeneus* (Cope and Packard). *American midland naturalist*, 666-701.

Graeter, G. J., K. A. Buhlmann, L. R. Wilkinson, & Gibbons, J. W. (Eds.). (2013). *Inventory and monitoring: Recommended techniques for reptiles and amphibians*. Partners in Amphibian and Reptile Conservation Technical Publication IM-1, Birmingham, Alabama

Hammerson, G. (2004). *Aneides aeneus*. *The IUCN Red List of Threatened Species* 2004: e.T1282A3385547

Hartzell, P., Glennie, C., Biber, K., & Khan, S. (2014). Application of multispectral LiDAR to automated virtual outcrop geology. *ISPRS Journal of Photogrammetry and Remote Sensing (88), 147-155.*

Hinkle, M. P., Gardner, L. A., White, E. R. I. C., Smith, W. H., & VanGundy, R. D. (2018). Remnant habitat patches support green salamanders (*Aneides aeneus*) on active and former Appalachian surface mines. *Herpetological Conservation and Biology*, *13*(3), 634-641..

John, R. (2016). Green salamanders. *Encyclopedia of Alabama.* Retrieved from http://www.encyclopediaofalabama.org/article/h-3850

John, R. (2017). Movement, occupancy, and detectability of green salamanders (*Aneides aeneus*) in Northern Alabama. M.S. Thesis. Auburn University. Auburn, AL.

John, R. R., Gitzen, R. A., & Guyer, C. (2019). Overnight movements of green salamanders (*Aneides aeneus*) in Northern Alabama. *Journal of Herpetology*, *53*(2), 158–164.

Johnson, A. N. (2002). Determining the genetic distances between sub-populations of *Aneides aeneus* in the Westvāco Wildlife and Ecological Research Forest. MS Thesis. Marshall University. Huntington, West Virginia.

Lentz, T. B., Allender, M. A., Thi, S. Y., Duncan, A. S., Miranda, A. X., Beane, J. C., ... & Stuart, B. L. (2021). Prevalence of *Ranavirus*, *Batrachochytrium dendrobatidis*, *B. salamandrivorans,* and *Ophidiomyces ophiodiicola* in amphibians and reptiles of North Carolina, USA. *Herpetological Review, 52*(2), 285-293.

Lips, K. R., Brem, F., Brenes, R., Reeve, J. D., Alford, R. A., Voyles, J., ... & Collins, J. P. (2006). Emerging infectious disease and the loss of biodiversity in a Neotropical amphibian community. *Proceedings of the National Academy of Sciences*, *103*(9), 3165-3170.

Lötters, S., Kielgast, J., Bielby, J., Schmidtlein, S., Bosch, J., Veith, M., ... & Rödder, D. (2009). The link between rapid enigmatic amphibian decline and the globally emerging chytrid fungus. *EcoHealth*, *6*(3), 358-372.

Milanovich J. R., Peterman W. E., Nibbelink N. P., & Maerz J. C. (2010). Projected loss of a salamander diversity hotspot as a consequence of projected global climate change. *PLoS ONE*, *5*(8): e12189.

Miller, D., Gray, M., & Storfer, A. (2011). Ecopathology of ranaviruses infecting amphibians. *Viruses*, *3*(11), 2351-2373.

Miloski, S. E. (2010). Movement patterns and artificial arboreal cover use of green salamanders (*Aneides aeneus*) in Kanawha County, West Virginia. MS, Marshall University, West Virginia, USA.

Mitchell, J. C., T. K. Pauley, D. D. Withers, S. M. Roble, B. T. Miller, A. L. Braswell, P. V. Cupp Jr. & Hobson, C. S. (1999). Conservation status of the southern Appalachian herpetofauna. *Virginia Journal of Science*, *50*:13-35.

Moffitt, D., Williams, L. A., Hastings, A., Pugh, M. W., Gangloff, M. M., & Siefferman, L. (2015). Low prevalence of the amphibian pathogen *Batrachochytrium dendrobatidis* in the Southern Appalachian Mountains. *Herpetological Conservation and Biology*, 10(1), 123-136.

Mount, R. H. 1975. *The Reptiles and Amphibians of Alabama.* University of Alabama Press.

NatureServe Explorer. (2011). *Aneides aeneus,* Green salamander. Retrieved from https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.103197/Aneides_aeneus

Newman, J. C., Mota J. L., Hardman, R. H., Dillman, J. W., & Barrett, K. (2019). Pathogen detection in Green Salamanders (*Aneides aeneus*) in South Carolina, USA. *Herpetological Review*, 50(3): 503-505.

Newman, J. C., Barrett, K., & Dillman, J. W. (2018a). Green salamander estimated abundance and environmental associations in South Carolina. *Journal of Herpetology*, *52*(4), 437–443.

Newman, J.C., Barrett, K., & Dillman J. W. (2018b). Green salamander post egg deposition. *Herpetological Review*, *49*(3): 511.

Office of Surface Mining Reclamation and Enforcement (OSMRE). 2007. Annual evaluation summary report for the regulatory and abandoned mine land reclamation programs administered by the state of West Virginia. Page 46. Charleston Field Office, West Virginia. (2007). Retrieved from http://www.osmre.gov/EvaluationInfo/2007.htm

Olson, D. H., & Saenz, D. 2013. Climate Change and Amphibians. U.S. Department of Agriculture, Forest Service, Climate Change Resource Center. Retrieved from https://www.fs.usda.gov/ccrc/topics/amphibians-and-climate-change

Patton, A., Apodaca, J. J., Corser, J. D., Wilson, C. R., Williams, L. A., Cameron, A. D., & Wake, D. B. (2019). A new green salamander in the southern Appalachians: evolutionary history of *Aneides aeneus* and implications for management and conservation with the description of a cryptic microendemic species. *Copeia*, *107*(4), 748-763.

Petranka, J. W. 1998. *Salamanders of the United States and Canada*. Smithsonian Books.

Rauch III, T. J., Lee, J. R., & Lawler, A. (2016). Green salamander (*Aneides aeneus*) populations in Mississippi: A preliminary update. *Journal of the Mississippi Academy of Sciences*, *61*(3), 222-227.

Riddell, E., & Sears, M. W. (2020). Terrestrial salamanders maintain habitat suitability under climate change despite trade-offs between water loss and gas exchange. *Physiological and Biochemical Zoology*, *93*(4), 310-319.

Rossell J. R., C. R., Williams, L. A., Cameron, A. D., Lawson, C. R., & Patch, S. C. (2019). Nest success and attributes of brood crevices selected by green salamanders (*Aneides aeneus*) on the Blue Ridge Escarpment. *American Midland Naturalist*, *181*(1), 40–52.

Smith, W. H., Slemp, S. L., Blackburn, M. N., & Wayland, J. (2015). Combining citizen science with traditional biotic surveys to enhance knowledge regarding the natural history of secretive species: Notes on the geographic distribution and status of the Green Salamander (*Aneides aeneus*) in the Cumberland Mountains of Virginia, USA. *IRCF Reptiles and Amphibians*, *22*(4), 135–144.

Smith, W. H., Slemp, S. L., Stanley, C. D., Blackburn, M. N., & Wayland, J. (2017). Rock crevice morphology and forest contexts drive microhabitat preferences in the Green Salamander (*Aneides aeneus*). *Canadian Journal of Zoology*, *95*(5), 353-358.

Smithsonian's National Zoo & Conservation. (2018). Green salamander. Retrieved from https://nationalzoo.si.edu/animals/green-salamander

Snyder, D. H. (1983). The apparent crash and possible extinction of the green salamander, *Aneides aeneus*, in the Carolinas. The Association of Southeastern Biologists Bulletin, pp. 82.

Sutton, W. B., Gray, M. J., Hoverman, J. T., Secrist, R. G., Super, P. E., Hardman, R. H., ... & Miller, D. L. (2015). Trends in ranavirus prevalence among plethodontid salamanders in the Great Smoky Mountains National Park. *EcoHealth*, *12*(2), 320-329.

Thigpen, T. F., Humphries, W. J., & Maerz, J. C. (2010). Effectiveness of using burlap bands to sample arboreal green salamander populations in the Blue Ridge Mountains of Georgia and North Carolina. *Herpetological Review*, *41*(2), 159-162.

U.S. Fish & Wildlife Service. (2019). Conserving South Carolina's at-risk species. Retrieved from https://www.fws.gov/southeast/pdf/fact-sheet/green-salamander.pdf

U.S. Fish and Wildlife Service (2015). Endangered and threatened wildlife and plants; 90-Day Findings on 31 Petitions. *Federal Register* 80:37568–37579.

Waldron, J. L., & Humphries, W. J. (2005). Arboreal habitat use by the green salamander, *Aneides aeneus*, in South Carolina. *Journal of Herpetology, 39*(3): 486-492.

Waldron, J. L., & Pauley, T. K. (2007). Green salamander (*Aneides aeneus*) growth and age at reproductive maturity. *Journal of Herpetology*, *41*(4), 638-644.

Williams, L. A., Parker, K. A., Lawson, C. L., & Cameron, A. D. (2020). Variation in seasonal detection probability and site abundance of populations of *Aneides aeneus* and *A. caryaensis* in North Carolina, USA. *Herpetological Conservation and Biology 15*(1):238–252.

Wilson, C. (2001). Green Salamander (*Aneides aeneus*). *Chattooga Quarterly*. Retrieved from https://chattoogariver.org/wp-content/uploads/2019/02/cq_01_spring.pdf